Appendix A

WIND MEASUREMENT IN GENERAL

The quality of wind data depends on the monitoring device selected, how the instrument is sited, how accurately it is calibrated, and how well it is maintained. The methods used to screen the raw data, as well as the methods used to assess the data once in edited form, also contribute to the quality of the final data.

Wind Measurement Devices

Many types of wind-measuring systems are commercially available. Most are ruggedly constructed, designed for a wide variety of applications, and require little attention for operation and maintenance. Such devices have been used for many years to measure winds in Montana.

The most common types of wind monitoring devices are anemometers, wind vanes, and combination wind sensors.

Anemometers measure wind speed. Commercially available anemometers operate on a variety of physical principles. Rotational cup and propeller anemometers are the most commonly used wind speed sensors. More esoteric designs generally are used only for very specialized studies.

Wind direction sensors, commonly called "wind vanes," operate by wind exerting pressure on a surface that rotates about a fulcrum. Although the standard vane measures only the horizontal wind direction, the bi-directional vane is free to move not only horizontally but also vertically (plus or minus 50 degrees or more from the horizontal). The shape and design of the vane surface will vary with the manufacturer.

Two types of sensors combine both wind speed and wind direction measuring capabilities into a single mechanical device. The propeller-vane sensor measures two-dimensional flow; the propeller-bivane sensor measures three-dimensional flow. Simple trigonometry is used with these wind component anemometers to determine wind speed and direction.

Varieties of these wind measuring instruments and their operational principles are presented in Table A-1.

Site Location

The most important siting considerations are anemometer height and spacing in relation to obstructions. The meteorological variables measured by the anemometer obviously are affected by large-scale surface features.

The effect of cities has been studied extensively. Documented effects include a decrease in average wind speed, a decrease in atmospheric stability, an increase in turbulence, an increase in temperature, and changes in precipitation patterns. These changes, of course, will affect the evaluation and interpretation of meteorological and air quality data collected in an urban area.

The effects of mountains and valleys on wind continue to be studied. Well-known effects include the channeling of flow up or down a valley, the creation of drainage flow, the establishment of lee-waves, and an increase in turbulence generated by friction.

The important point is that almost any physical object has an effect on the wind. In fact, it is difficult to find a site that is completely free of obstructions. This being the case, the choice of a site for collecting meteorological data that will be most representative of an area must be made with a complete understanding of the meteorological parameters being investigated, the large-scale geographic area, the vertical structure of the atmosphere, and the potential uses of the data.

Once a location is chosen, the characteristics of

Table A-1
Types of Wind Sensors and Their Operational Principles

Physical Principle	Wind Sensor Type	Measurement
Rotation	Cups	Horizontal speed
	Vane-oriented Propeller	Horizontal speed
	Bivane-oriented Propeller	Total speed
	Fixed Propeller	Three-dimensional components on perpendicular axes
Pressure	Plate	Horizontal speed
	Tube	Horizontal speed
	Bridled cups	Horizontal speed
Cooling	Hot wire	Directional flow component
	Hot thermopile	Directional flow component
	Hot film	Directional flow component
Sound	Sonic	Directional flow component
Vortex-shedding	Vane-oriented shape	Horizontal speed
Ion-flow	Transport	Horizontal speed

the site should be completely documented. This should include complete site descriptions, topographic maps, photographs of the site, and a description of the area that is adequately represented by the site. Attention to this last point is very important, for it will allow a more rational interpretation of the data by subsequent investigators. The documentation might state, for example, that a site adequately represents a certain section of a particular valley, the urban part of a given city, or several rural counties. The nature and purpose of the site, in any event, should be clearly described to assist those who may use the data.

Instrument Calibration

Wind sensors should be calibrated when they are installed and every six months thereafter. Calibration also is required after the sensors are repaired. The user's manual accompanying the measurement device generally will specify the calibration methods to be followed. Most systems will require a DC voltage input which represents some output value. In other cases, they may require a frequency to represent some output value. Many systems have a built-in calibration unit to test part of the system.

Wind vanes must be oriented to true north when installed. This orientation must be checked at least once every six months. In addition, the sensors must be set so that they are absolutely vertical.

Instrument Maintenance

A sound, preventive maintenance program for the sensors also should be established. The equipment should be checked for potential problems at least once a month. The manufacturer's recommendations for maintenance and parts replacement also should be followed.

Data Screening

Once data are collected, they should be reviewed to screen out possible incorrect data points before they are put into accessible storage or passed on to the users. While the purpose of a quality assurance program is to avoid generating bad data, it is impossible to do so completely. Even in the best planned and best conducted programs, undetected errors can be generated by faulty equipment, noisy data transmission lines, faulty key punching, and a myriad of other causes. In both automatic and manual data screening, the most obvious checks should be performed first. These checks should include making sure that the data actually exist and are properly identified, and that forms and files are filled out properly.

Methods of editing or screening meteorological data usually involve comparing the measured values with an expected value or range of values. Techniques for checking the measured values usually fall into one or more of the following categories:

- Comparison with upper and/or lower limits on the allowed range of data;
- Comparison with known statistical distributions of the data;
- Comparison with spatial and/or temporal data fields;
- Comparison based on known physical relationships.

If data do not pass a validation procedure, the screener has two basic choices: (1) to eliminate the questionable data from the file; or (2) to flag it for further examination. Automatically discarding data is a feasible option if the screening procedure is carefully designed and each datum is not of high value. Records must be kept of all discarded data, so that the reason for the fault may later be found and corrected. With flagged data, the screener must examine the data and decide whether they are acceptable for use. If data are deemed unacceptable, it may be possible to correct them. If any values are corrected, this should be noted in the data file. Alternatively, data of questionable value may be kept in the data file under a flagged status, with a notation of why they are thought to be questionable. The user can then decide whether he or she wants to use these data. The collecting agency, however, typically is in the best position to make a decision on the validity of the data.

Data Interpretation

To assess the wind energy potential of an area, it often is necessary to evaluate data collected by different agencies, at different times, using different methods. When comparing data sets, the most important factors to consider are:

- The periods of time during which the data were collected;
- The locations of the monitoring sites;
- The anemometer heights;
- The methods used to collect and analyze the data;
- The averaging periods of the data;
- The quality assurance procedures followed.

The period of time represented by the data is important because wind speed and direction vary from year to year. Ideally, at least five years of data should be available to characterize the long-term wind climatology of an area. When comparing data from different sites, it is best if the data are for the same period of time; otherwise, the comparison may be biased due to the interannual variability of the wind.

It is important to know the physical characteristics of a site because of the strong influence that topography has on wind direction and speed. Knowledge of an area's topography and possible obstructions to air flow is useful in determining the wind regimes that influence an area (see Chapter III).

Anemometer height is of critical importance when comparing wind data from different sites because wind speed usually increases with height. If different sites have different anemometer heights, it may be useful to adjust the wind speed values to a standard reference height by means of the one-seventh power law. Power laws, however, give only an approximation of wind speed variation with height, not actual values (see Chapter V).

The methods used to collect and analyze the data also should be known when comparing data from different sites. Computerized data acquisition systems, which measure wind speed and wind direction every few seconds, generally give more accurate results than manual reduction of data from stripchart records.

To compare wind data sets, the data averaging time also must be known. Most data sets represent one-hour averages of wind speed and direction, although some monitoring studies gather and organize data differently, with averaging times of seconds or minutes. Users must be particularly cautious when a data point representing a period of only a few minutes is said to represent a complete hour.

Finally, the quality assurance procedures followed should be examined. Of particular importance are the methods and frequency of equipment calibration and the detection and treatment of erroneous data values.